Using MBSE Techniques to Perform Early Validation on the Data Handling Unit of a Spacecraft

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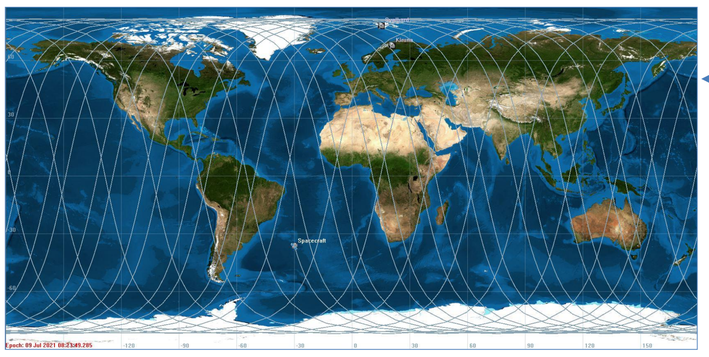
Research Aim

Demonstrate that transferring from a document-based to model-based systems engineering approach enables early validation of the functional system through high-level simulation of the design artefacts.

Use Case



- LEO Spacecraft - Phase B1
- Radar Instrument
  On over land / Off over ocean
- X-band Downlink Antenna
  On over groundstation / Off
- Memory (3 Directories)
  Reading / Writing / Both

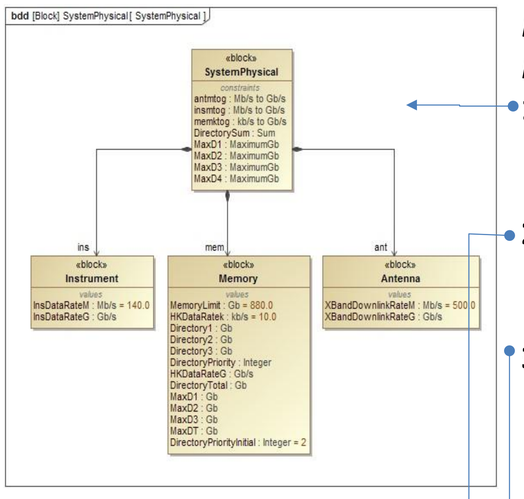
- The spacecraft has limited memory onboard – assigned 880 Gb
- The mission has been defined – sun synchronous
- High-level system information is available – system modes, activities, etc.

- Can we produce a system model that validates the memory allocation?

Objectives

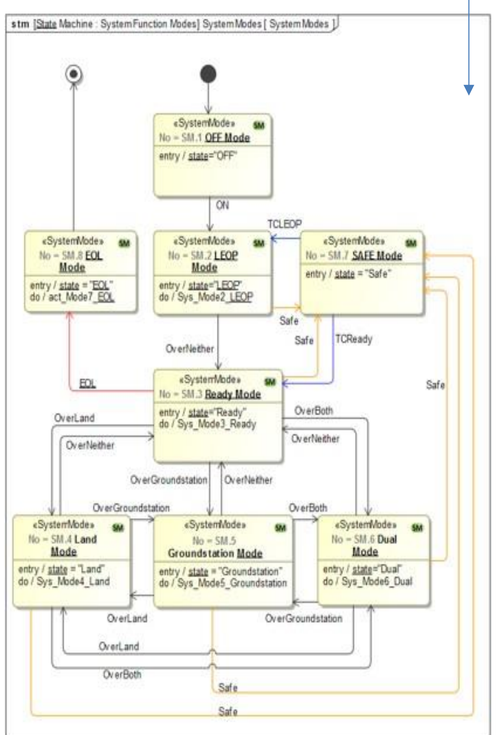
- Validate total memory allocation
- Optimise memory directory sizes
- Validate model against Excel results

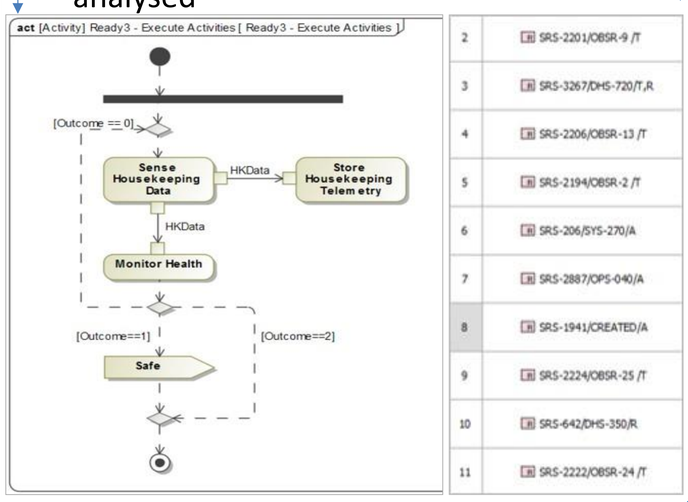
Methodology



Based on Estable's 'Federated and Executable Models' methodology[1].

1. **Physical Architecture** of the system defined, containing parameters of the system
2. **Functional Architecture** of the system defined, starting with system mode diagram
3. **Functional Architecture** of the system continues, with system activities and corresponding calculations defined (written in Matlab and called)
4. **Requirements** stored in the system model. These are rewritten as mathematical constraints and linked to the architecture
5. **Mission Profile** can then be loaded into system model, and the system response analysed

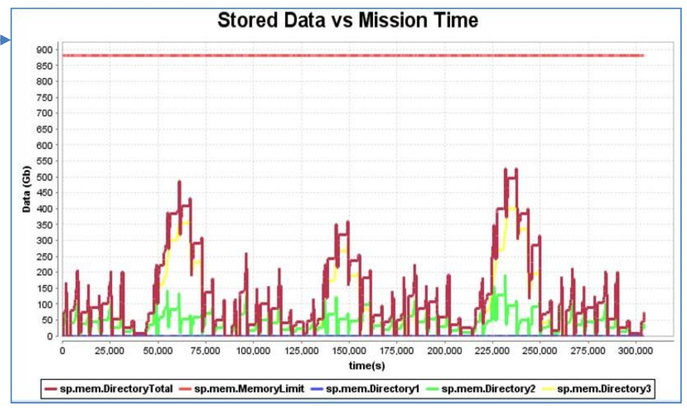




2	SRS-2201/OBSR-9 /T
3	SRS-3267/DHS-720/T,R
4	SRS-2206/OBSR-13 /T
5	SRS-2194/OBSR-2 /T
6	SRS-206/SYS-270/A
7	SRS-2887/OPS-040/A
8	SRS-1941/CREATED/A
9	SRS-2224/OBSR-25 /T
10	SRS-642/DHS-350/R
11	SRS-2222/OBSR-24 /T

Results

Memory Allocation
Full simulation results show a ~40% margin – i.e. memory usage only ever reaches ~60% of memory limit



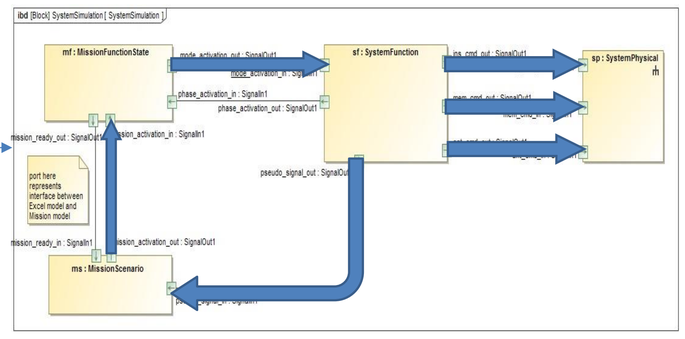
Directory Optimisation
Suggested optimised partitioning between the three directories for this mission profile

Requirements Check
Model produced performs calculations and automatically checks results against requirements (pass/fail)

DataGb : Gb	4.7520
DataLimitGb : Gb	10.0000
DataMb : Mb	4752.0000
DownlinkRate : Mb/s	467
RecordRate : Mb/s	132
SigNumber : Integer	1
DataCheck : No more than	No more than Data Limit@6f4215c2
MbtoGb : Mbit to Gbit {Data	Mbit to Gbit@1feb604f
RecordRateCheck : Record	RecordRateConstraint@6acd432d

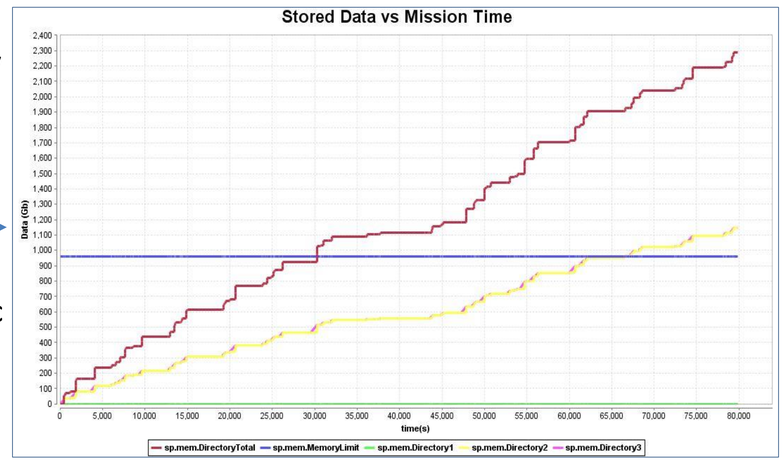
Validated Model
The model produced was validated against Excel data produced by a subcontractor asked to perform the same study

Simulation Template
This template can be used in the future to define and execute the functional architecture of a system for early validation

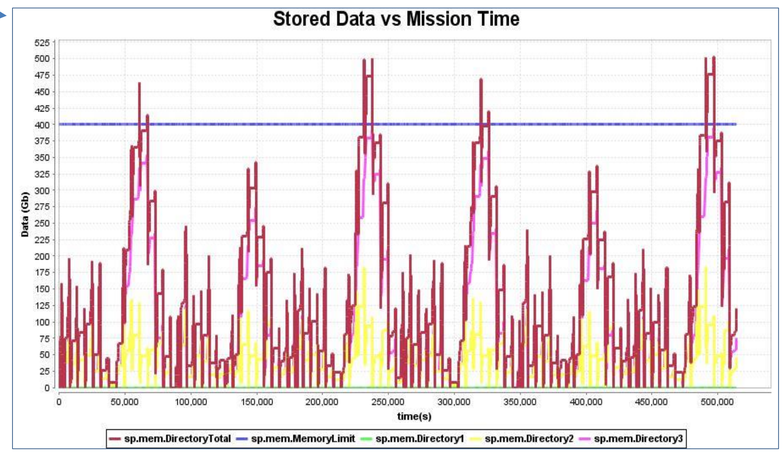


Future Work

Model Flexibility
Demonstrate the flexibility of the model developed in this work by exploring contingency modes of operation (e.g. antenna failure), changes to requirements, system spec changes, etc.



Mission Operations Template
Using this model as a basis, produce a model template which will contain early phase functional design artefacts, and which allows the user to develop interrogative Matlab-, state machine-, activity-based simulations



Conclusions

This work has demonstrated that by transferring from a document-based to a model-based systems engineering methodology, the design artefacts available at this early stage in the design process (Phase B1) can be executed and used to perform early validation on the high-level functional design of the system.

Future work will develop this model into a template capable of early functional validation using Matlab-, state machine, activity-based interrogative simulations.

Acknowledgements & Contact Details

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1. S. Estable, "Application of the 'Federated and Executable Models' MBSE Process to Airbus Orbital Servicing Missions," in *Phoenix Integration International Users' Conference*, 2018

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